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Madison Battaglia  
*Yale University*

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## The Run on Repo and Bank Stock Returns

### Cover Page Footnote

I would like to first express my deepest appreciation to my advisor, Janet L. Yellen Professor of Finance and Management of Yale School of Management Andrew Metrick, Ph.D., for his invaluable expertise, time, support, patience, and trust throughout the process of researching and writing my thesis. I want to acknowledge his generous mentorship throughout my four years at Yale University. I wish to thank him for providing me with the sale and repurchase agreement haircut data. Second, I would like to thank all of my professors and the Department of Economics throughout my undergraduate career at Yale University. They inspired me to challenge myself and produce my best academic work. I am grateful I had the opportunity to culminate what I have learned from economics into my thesis. Lastly, I owe a great deal of thanks to my family, whose unwavering support, love, and willingness to listen sustained me for the past six months and the past twenty-two years. All errors are my own.

# The Run on Repo and Bank Stock Returns

By **Madison Marie Battaglia**<sup>1</sup>

<sup>1</sup>*Department of Economics, Yale University*

## ABSTRACT

The run on the sale and repurchase market (“run on repo”) was at the nexus of the Financial Crisis of 2007-2009. Up until now, the economics literature has not studied the effect of sale and repurchase agreement (“repo”) haircuts on bank stock returns using an empirical economic approach. I utilize private repo haircut data from 2007Q1-2009Q1 supplemented with bank stock returns, total reserve balances, and market rate of returns and risk-free rate of returns data to trace the path of crisis from repurchase agreements into a market that had no connection to housing. In linear model regressions, I find that repo haircuts on BBB+/A Corporates, AA-AAA Corporates, A-AAA ABS-Auto/CC/SL, AA-AAA ABS-RMBS/CMBS, AA-AAA CLO, and Unpriced CLO/CDO are negatively associated with bank stock returns during the Financial Crisis. The results suggest that there is an underlying force driving the co-movement of bank stock returns with repo haircuts.

## INTRODUCTION

The Financial Crisis of 2007-2009 was a banking panic in the sale and repurchase agreement market, a multi-trillion dollar market that dramatically shrank with the “run on repo”: a securitized banking system run driven by the withdrawal of sale and repurchase agreements (“repo”). Net repo financing collapsed by about \$1.3 trillion by the first quarter of 2009, down more than half of its pre-Crisis total in the second quarter of 2007 (Gorton and Metrick 2012). Significant effects of this run on repo remain a gray area because of the lightly regulated, or lack thereof, institutions’ gap in comprehensive data. In this paper, I aim to establish the impact of the sale and repurchase agreement market on bank performance during the Financial Crisis. I supplement a private dataset with the best available official data sources to study the effect of 9 different categories of asset classes of collateral repurchase agreement haircuts on bank stock returns. The economics literature has not looked at the bank stock returns effects of repo haircuts. In linear model regressions, I provide evidence that repo haircuts on BBB+/A Corporates, AA-AAA Corporates, A-AAA ABS-Auto/CC/SL, AA-AAA ABS-RMBS/CMBS, AA-AAA CLO, and Unpriced CLO/CDO are negatively associated with bank stock returns during the Financial Crisis. My analysis suggests that there is an underlying force driving the co-movement of bank stock returns with repo haircuts.

Increasing home ownership rates has been identified as a key goal for the U.S. Government via modern housing finance during the Great Depression with the New Deal’s National Housing Act of 1934 (Fishback, Horrace, and Kantor 2001). The subprime mortgage market was a successful financial innovation, aimed at promoting access to mortgage finance in order to own homes to disproportionately poor and minority people, that originated a total of about \$2.5 trillion of subprime mortgages in 2001-2006, but its necessary interlinked unique security design resulted in a loss of information to investors and subsequent Panic of 2007 (Gorton 2008; Inside Mortgage Finance 2007). In 2006 and 2007, 80 percent of subprime mortgages were financed through securitization (Gorton

2009). The sale and repurchase market is a very large, short-term market that provides financing for a wide range of securitization activities and financial institutions.

The 2007-2009 Financial Crisis was special because it was a run on repo: a system-wide bank run in the securitized banking system that was driven by the withdrawal of repurchase agreements, instead of a bank run in the traditional banking system that is driven by the withdrawal of deposits. Traditional banking involves making and holding loans, with insured demand deposits as the main source of funds. Securitized banking involves packaging and reselling loans, with repo agreements as the main source of funds. According to Gorton and Metrick (2009), securitized banking activities were central to the operations of firms formerly known as “investment banks” (e.g. Bear Stearns, Lehman Brothers, Morgan Stanley, Merrill Lynch), but they also play a role at commercial banks, as a supplement to traditional banking activities of firms like Citigroup, J.P. Morgan, and Bank of America. The Crisis was not only unique because of where the run on repo spread, but also the dynamics of who facilitated it. Gorton and Metrick (2012) find that the run on repo was predominantly driven by the flight of foreign financial institutions, domestic and offshore hedge funds, and other unregulated cash pools.

In 2007, the total size of the repo market was about \$12 trillion (counting repo and reverse repo), including \$2.5 trillion of tripartite repo, compared to total assets in the U.S. banking system of \$10 trillion (Geithner 2008).<sup>1</sup> According to Hørdahl and King (2008), “the (former) top US investment banks funded roughly half of their assets using repo markets, with additional exposure due to off-balance sheet financing of their customers”. Securitized banking rates have been rising, with the ratio of broker-dealer (investment) banks total assets to traditional banking banks’ total assets having grown

<sup>1</sup> In tripartite repo, a custodian bank or clearing organization acts as an intermediary between the two repo parties. There are no data that quantify the amount of bilateral repo (Gorton 2009).

from about six percent in 1990 to a peak of 30 percent in 2007, according to Federal Flow of Funds data (Gorton and Metrick 2009).<sup>2</sup> In 2007, the United States Bankruptcy Court upheld a new stance on repurchase agreements, ruling that repurchase agreements involving mortgage loans are protected under the safe harbor provisions of the Bankruptcy Code, but servicing rights are not (Schweitzer, Grosshandler, and Gao 2008); in the case that one party defaults, the non-defaulting party is allowed to terminate the contract and keep the cash or bonds.

The Financial Crisis that began in August 2007 is analogous to the banking panics of the 19th century in which depositors en masse ran to their banks to withdraw cash in exchange of demand and savings deposits. Since the banking system had to suspend convertibility because the cash had been lent out and loans were illiquid, the clearinghouses issued loan certificates to member banks in place of currency for the payment of depositors' claims (Gorton 1985). The banking system in the 19th century was insolvent because of the discount on these certificates. The 2007-2009 Financial Crisis is similar in that contagion led to withdrawals in the form of unprecedented high repo haircuts and even the cessation of repo lending on many forms of collateral (Gorton and Metrick 2009). The banking system in 2008 was insolvent because several large firms went bankrupt, were forced into rescue, or required government assistance to stay in business.

Traditional banking runs were ended in the United States in the 1930s with the introduction of deposit insurance and discount-window lending by the Federal Reserve (Gorton and Metrick 2009). However, when deposit insurance was capped at \$100,000 per account, institutions such as pension funds, mutual funds, states and municipalities, and cash-rich nonfinancial companies lacked easy access to safe, interest-earning, short-term investments; the securitized banking system provides a solution to this problem (Gorton et al. 2010).

Safe assets play a critical role in the economy. A safe asset can be used to transact without fear of adverse selection because it is always taken at face value with no questions asked (NQA), meaning a safe asset is relatively immune to the costly production of private information about its value (Holmström 2015). Dang, Gorton, and Holmström (2015) define this attribute as information insensitivity. Treasury yields are reduced by 73 basis points, on average, from 1926 to 2008 due to the convenience yield in the form of both the liquidity and safety attributes of Treasuries, and the existence of a convenience yield implies that U.S. Treasuries are non-Ricardian (Barro 1974; Gorton and Ordoñez 2013; Krishnamurthy and Vissing-Jorgensen 2012). The Financial Crisis of 2007–2009 showed, once again, that privately produced safe assets, that is short-term debt like sale and repurchase agreements, are not always safe; short-term safe debt is subject to runs, threatening systemic collapse of the financial system and having important implications for macroeconomics and monetary policy (Gorton 2017).

<sup>2</sup> Federal Reserve Flow of Funds data on repo only cover the U.S. primary dealers and do not capture the increasing share of repo in total financing for each kind of bank. Therefore, the Federal Reserve numbers understate the increased role of repo finance over time.

Banks may act as secret keepers to decrease the risk of contagion spreading from the repo market to the stock market. Banks produce money that is not sensitive to information, either public or privately produced, even when it must be backed by risky assets that require evaluation by being opaque; however, the trade-off between less safe liquidity and more risky liquidity determines which firms choose to fund projects through banks and which ones through capital markets (Dang et al. 2017). The idea that it may be optimal to keep information secret is not new and has been articulated in the early release of information destroying future insurance opportunities, a model in which banks acquire information before depositors acquire it, a bank's preferences to keep information secret even though it must then use a non-contingent deposit contract, and diversified intermediation (e.g. banks) mitigating information appropriability problems (Breton 2006; Diamond and Dybvig 1983; Hirshleifer 1971; Kaplan 2006). Researchers have concluded that debt-on-debt is the optimal structure of contracts to solve the problem of endogenous private information acquisition as well as the exogenous arrival of public news; this is because debt is least information sensitive and a collapse of trade in debt funding markets (e.g. a financial crisis) is a discontinuous event that occurs when public news about fundamentals makes information insensitive debt to become information sensitive (Dang, Gorton, and Holmström 2015). In addition, banks structure their balance sheets to take advantage of the imperfect correlation between deposit withdrawals and loan commitment takedowns, resulting in synergies between the two activities (Kashyap, Rajan, and Stein 2002).

A large part of the accounting literature has focused on the potential costs of firms' disclosure, specifically in stock markets. Diamond and Verrecchia (1991) demonstrate that revealing public information to reduce information asymmetry can reduce a firm's cost of capital, but it can have the opposite effect by reducing liquidity in the stock market. Banks have always been opaque and it is contingent on examiners to uncover secrets. Studies show economically significant bank stock price and volume reactions as a result of the quarterly public release of Call Reports; strong negative bank stock price and abnormal return effects as a result of bank examination downgrades or dividend reductions; and significantly positive abnormal returns as a result of the SEC mandate that bank holding company CEOs must certify the accuracy of their financial statements (Badertscher, Burks, and Easton 2018; Berger and Davies 1998; Bessler and Nohel 1996; Hirtle 2006). In particular, the responses to the Financial Crisis maintained bank anonymity as emergency lending facilities were carefully designed, with complicated and opaque asset-backed securities (ABS) and mortgage-backed securities (MBS) backing sale and repurchase agreements, to keep bank borrowers from having their identities revealed (Dang et al. 2017). Further, the Securities and Exchange Commission (SEC) adopted extraordinary measures during the recent financial crisis, banning the short selling of 797 financial stocks for the 14 trading days from September 19th through October 8th of 2008; the ban was intended to prevent speculators from placing excessive downward pressure on the stocks of already troubled financial firms (Release No. 34-58592 / September 18, 2008).<sup>3</sup>

<sup>3</sup> In an amendment to the order, the SEC gave authority to the exchanges to add additional stocks to the banned list. Altogether, over 1,000 stocks were brought under the ban within several days of the order (Securities and Exchange Commission 2008b).

This paper proceeds as follows. In Section II, I provide background for my analysis of sale and repurchase agreements. In Section III, I describe the data sources, present summary statistics, and illustrate the trends in the data on repo haircuts, bank stock returns, total reserve balances, and market and risk-free rate of returns. In Section IV, I explain my econometric methodology and Section V reports the main empirical results of my analysis. In Section VI, I discuss my arguments and conclude the paper. In the Appendix, I define some of the paper's terminology and the asset classes of collateral that are used in my empirical analysis.

## BACKGROUND

There are a few differences between traditional banking and securitized banking. The classic picture of the financial intermediation of mortgages by the traditional banking system is as follows: (step 1) depositors transfer money to the bank in return for a checking or savings account that can be withdrawn at any time, interest rates on deposits, and deposits insured by the government; (step 2) the bank loans these funds to a borrower in return for a promised repayment through a mortgage on a property; and (step 3) the bank holds this mortgage and other non-mortgage loans on its balance sheet in adherence of minimum reserve levels set by regulators. The securitized banking system is a version of the above and works as follows: (step 1) investors transfer money to the bank in return for collateral; (step 2) the bank outsources underwriting loans to a direct lender; (step 3) the bank securitizes most of the mortgage loans to outside investors; and (step 4) the bank uses the outputs of the securitization as collateral, creating a cycle that ultimately breaks down during the Financial Crisis.

In this paper, I address the implication of one important difference between the traditional banking and securitized banking systems: sale and repurchase agreements. In step 2 of the securitized banking system, the deposit-collateral transaction takes the form of a repo agreement.<sup>4</sup> A repurchase agreement is a financial contract in which the bank (i.e. borrower) transfers specified securities (i.e. collateral) to the depositor (i.e. lender) in exchange for cash and the bank agrees to repurchase the securities shortly afterwards, usually at a slightly higher price. The term at which a repo agreement is typically set to mature is overnight. The repo rate is the amount the investor charges for the deposit, expressed as a percentage of the principal. My paper focuses on the repo haircut: the percentage difference between an asset's market value and the amount that can be used as collateral for a loan.<sup>5</sup> The size of this markdown is largely based on the risk of the underlying asset. Gorton and Metrick (2009) find that changes in the LB-OIS spread, a proxy for counterparty risk, was strongly correlated with changes in credit spread and repo rates for securitized bonds; accordingly, concerns about the liquidity of markets for the bonds used as collateral led to increases in repo haircuts.<sup>6</sup> In other words, riskier assets receive larger haircuts.

4 For background on the repo market, see Bank for International Settlements (1999) and Corrigan and de Terán (2007).

5 A haircut is defined as  $H = 1 - \frac{D}{C}$ , where D is the amount lent to the bank by the lender and C is the collateral.

6 The LIB-OIS is the spread between the LIBOR rate (for unsecured interbank borrowing) and the OIS, the rate on an overnight interest swap (a proxy for the

For decades, repurchase agreements have been recognized as a form of money and considered a part of the money supply (Federal Reserve Bank of New York 2008); the Federal Reserve counted repo in the monetary aggregate M3, which was discontinued in 2006.<sup>7</sup> Securities that function as money have specific properties of being short term debt and backed by diversified portfolios, which Gorton and Pennacchi (1990) and Dang, Gorton, and Holmström (2010b) describe as information-insensitive securities. Banks try to produce these safe securities with the purpose of not much change in their value and no benefit of private information speculation about their value. The Financial Crisis was a problem with a specific type of private money creation, repos, in which "liquidity dries up" because of a "loss of confidence" (Gorton and Metrick 2010).

One important purpose of repos is that they can be rehypothecated. Hypothecate means to pledge collateral. Rehypothecation is when a secured party, such as a dealer, a bank, or other financial institution, repledges collateral pledged in one transaction with an unrelated third party in an unrelated transaction (Johnson 1997). Gorton and Metrick (2010) explain that rehypothecated collateral is associated with money velocity because the same collateral can support multiple transactions, in the same way that one dollar of cash can lead to a multiple of demand deposits at a bank. This cash like function of repo is another example of how repo acts as money.

The repo market can be split into two main segments: tri-party repo and bilateral repo. In tri-party repo, the clearing banks act as an intermediary, facilitating settlement between the two parties in the repo transaction; the bilateral repo market has investors and collateral providers directly exchange money and securities, absent a clearing bank (Securities Industry and Financial Markets Association (SIFMA) 2020). The tri-party institutions are highly regulated and thus have comprehensive data. However, much of bilateral repo involves unregulated institutions (e.g. offshore institutions), so there is a significant data gap. Survey evidence from the Bond Market Association (2005) finds that bilateral repo was about three times as large as tri-party repo in 2004. In Gorton and Metrick's (2012) research, they provide an answer to "who ran on repo?": "the statistical discrepancy [between the Federal Reserve Flow-of-Funds data and the Bond Market Association survey evidence] ran on repo".<sup>8</sup> That is, the run was predominantly driven by the flight of foreign financial institutions, domestic and offshore hedge funds, and other unregulated cash pools (Gorton and Metrick 2012).

Securities dealers are at the heart of the repo market as they operate as intermediaries in both the aforementioned segments. Those additional risk-free rate) (Gorton and Metrick 2009).

7 "On March 23, 2006, the Board of Governors of the Federal Reserve System will cease publication of the M3 monetary aggregate. The Board will also cease publishing the following components: large-denomination time deposits, repurchase agreements (RPs), and Eurodollars....M3 does not appear to convey any additional information about economic activity that is not already embodied in M2 and has not played a role in the monetary policy process for many years. Consequently, the Board judged that the costs of collecting the underlying data and publishing M3 outweigh the benefits" (Federal Reserve 2005).

8 See Federal Reserve Flow-of-Funds L.207 Federal Funds and Security Repurchase Agreements (2019) and Bond Market Association (2005) survey evidence.

Panel A: Repo Haircuts			
Series	Periods	Mean	Standard Deviation
BBB+/A Corporates	Whole period	0.05	0.10
	First half of 2007	0.00	0.00
	Second half of 2007	0.00	0.00
	All of 2007	0.00	0.00
	All of 2008	0.09	0.12
AA-AAA Corporates	Whole period	0.05	0.10
	First half of 2007	0.00	0.00
	Second half of 2007	0.00	0.00
	All of 2007	0.00	0.00
	All of 2008	0.09	0.12
A-AAA ABS-Auto/CC/SL	Whole period	0.11	0.11
	First half of 2007	0.00	0.00
	Second half of 2007	0.08	0.12
	All of 2007	0.05	0.10
	All of 2008	0.17	0.07
AA-AAA ABS-RMBS/CMBS	Whole period	0.09	0.10
	First half of 2007	0.00	0.00
	Second half of 2007	0.02	0.02
	All of 2007	0.01	0.02
	All of 2008	0.17	0.07
<AA ABS-RMBS/CMBS	Whole period	0.11	0.10
	First half of 2007	0.00	0.00
	Second half of 2007	0.03	0.05
	All of 2007	0.02	0.04
	All of 2008	0.19	0.06
Unpriced ABS/MBS/All Sub-Prime	Whole period	0.39	0.43
	First half of 2007	0.00	0.00
	Second half of 2007	0.11	0.10
	All of 2007	0.06	0.09
	All of 2008	0.68	0.40
AA-AAA CLO	Whole period	0.10	0.11
	First half of 2007	0.00	0.00
	Second half of 2007	0.02	0.02
	All of 2007	0.01	0.02
	All of 2008	0.19	0.09
AA-AAA CDO	Whole period	0.29	0.36
	First half of 2007	0.00	0.00
	Second half of 2007	0.07	0.07
	All of 2007	0.04	0.07
	All of 2008	0.52	0.36
Unpriced CLO/CDO	Whole period	0.33	0.35
	First half of 2007	0.00	0.00
	Second half of 2007	0.14	0.10
	All of 2007	0.08	0.10
	All of 2008	0.56	0.33
Repo-Haircut Index	Whole period	0.17	0.18
	First half of 2007	0.00	0.00
	Second half of 2007	0.05	0.04
	All of 2007	0.03	0.04
	All of 2008	0.30	0.16
Panel B: Bank Stock Returns			
Series	Periods	Mean	Standard Deviation
Bank Stock Returns	Whole period	-0.02	0.10
	First half of 2007	0.00	0.05
	Second half of 2007	-0.01	0.06
	All of 2007	-0.01	0.05
	All of 2008	-0.03	0.12
Ri – Rf	Whole period	-0.02	0.10
	First half of 2007	-0.01	0.05
	Second half of 2007	-0.01	0.06
	All of 2007	-0.01	0.05
	All of 2008	-0.03	0.12
Panel C: Total Reserve Balances			
Series	Periods	Mean	Standard Deviation
Total Reserve Balances	Whole period	0.20	0.88
	First half of 2007	0.04	0.21
	Second half of 2007	0.02	0.27
	All of 2007	0.03	0.24
	All of 2008	0.36	1.19
Panel D: Market Rate of Return and Risk-Free Rate of Return			
Series	Periods	Mean	Standard Deviation
Rm – Rf	Whole period	-0.01	0.05
	First half of 2007	0.01	0.02
	Second half of 2007	0.00	0.03
	All of 2007	0.00	0.03
	All of 2008	-0.02	0.07

**Table 1. Summary Statistics.** This table reports the summary statistics for repo haircuts, Panel A; bank stock returns, Panel B; total reserve balances, Panel C; and market rate of return and risk-free rate of return. For each series, I show summary statistics of mean and standard deviation for the whole period and four subperiods: first half of 2007, second half of 2007, all of 2007, all of 2008. All variables given in this table are defined in the Appendix. The samples are restricted to observations that are used in the one-factor linear model regression.



tional market participants who lend cash collateralized by securities are mostly comprised of large, institutional investors of cash pools that include asset managers, pension funds, insurance companies, securities lenders, and money market funds (Aguiar, Bookstaber, and Wipf 2014; Pozsar 2011). Those other market participants who seek funding are levered investors like hedge funds (Aguiar, Bookstaber, and Wipf 2014). Also, securities dealers intermediate between those looking to earn extra yield by lending securities, such as pension, sovereign wealth, mutual, exchange-traded, and insurance funds, and those looking to borrow specific securities, such as hedge funds and broker-dealers (Baklanova, Copeland, and McCaughrin 2015). Furthermore, the Federal Reserve has conducted temporary open market operations by using repo and reverse repo agreements with the intention to manage the supply of total reserve balances such that the federal funds rate is kept within target policy ranges deemed appropriate by the Federal Open Market Committee (FOMC) (Federal Reserve Bank of New York 2014).<sup>9</sup>

In the repo market, the collateral often consists of securitized bonds, which are the liabilities of a special purpose vehicle (SPV). A SPV finances a large portfolio of loans (e.g. home mortgages, auto loans, credit card receivables, and student loans) by issuing investment-grade securities (i.e. bonds with ratings in the categories of AAA, AA, A, BBB) with different seniority (i.e. tranches) in the capital markets. Gorton and Souleles (2007) conclude that SPVs exist in large part to reduce bankruptcy costs. The securitization of non-mortgage loans creates asset-backed securities (ABS), which are residential mortgage-backed securities (RMBS) when they are backed by asset pools of residential mortgages and commercial mortgage-backed securities (CMBS) when they are backed by asset pools of commercial mortgages. Collateralized debt obligations (CDO) and collateralized loan obligations (CLO) are SPVs that issue different tranches of risk in the capital markets and use the proceeds to buy a portfolio of fixed income assets or commercial bank loans, respectively.

## DATA

### Repo Haircut Data

My data collection process starts when Andrew Metrick, Janet L. Yellen Professor of Finance and Management of Yale School of Management, who has done extensive research into financial stability, provides a private dataset of 844 daily repo haircut observations on each of 9 different categories of asset classes of collateral from 2005Q4-2009Q1. The data is extracted from one broker dealer engaging in repo transactions with other banks in the interbank market regarding the independent variables of interest, repo haircuts for BBB+/A Corporates, AA-AAA Corporates, A-AAA ABS-Auto/CC/SL (auto/credit cards/student loans), AA-AAA ABS-RMBS/CMBS, <AA ABS-RMBS/CMBS, Unpriced ABS/MBS/All Sub-Prime, AA-AAA CLO, AA-AAA CDO, and Unpriced CLO/CDO.

<sup>9</sup> In accordance with the Dodd-Frank Wall Street Reform and Consumer Protection Act, the Federal Reserve now provides transaction-level data on its repo and reverse repo trades with primary dealers (Federal Reserve Bank of New York 2020); these data complement operational data also available from the Federal Reserve Bank of New York.

Repo haircuts are not uniform across asset classes because repo haircuts are a function of the default probabilities of the two parties to the transaction and the information sensitivity to the collateral (Dang, Gorton, and Holmström 2010b). The study's strengths are that the bank that provided the data anonymously is a large, well-known institution and I know of no other large datasets of repo haircuts.<sup>10</sup> Its limitation is the data are not representative because I do not have data from other banks.

I subset the data for bi-weekly observations to sync with the total reserve balances data, where weekly data observations repeat for 2 consecutive weeks. Additionally, while Andrew Metrick's initial dataset goes back to 2005Q4, my dataset includes bi-weekly repo haircuts in 2007Q1 and after to coincide with the timeline of the Financial Crisis. The final subset sample of repo haircuts consists of 54 bi-weekly repo haircut observations on each of the 9 different categories of asset classes of collateral from 2007Q1-2009Q1. Finally, I create matched samples with the 3 other data sources that follow and then I merge the 4 datasets to comprise my main dataset.

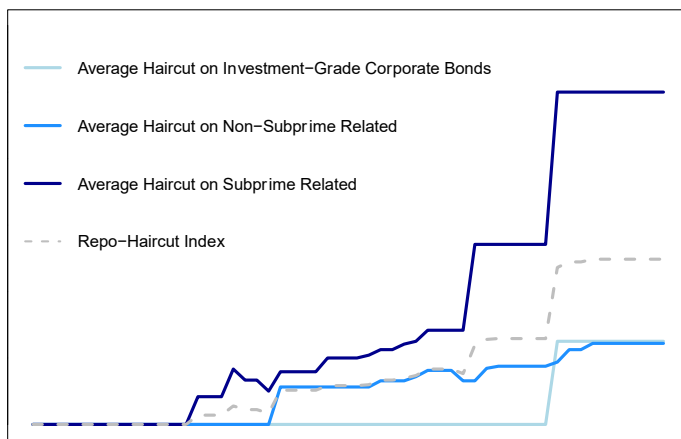
Table 1 displays summary statistics.<sup>11</sup> Throughout Table 1 there are five periods shown: the whole period (January 2007-January 2009), the first half of 2007, the second half of 2007, all of 2007, and "all of 2008" (which also includes January 2009). Panel A shows repo haircuts in the interbank repo market. Different categories of collateral are shown in each row: BBB+/A Corporates, AA-AAA Corporates, A-AAA ABS-Auto/CC/SL, AA-AAA ABS-RMBS/CMBS, <AA ABS-RMBS/CMBS, Unpriced ABS/MBS/All Sub-Prime, AA-AAA CLO, AA-AAA CDO, Unpriced CLO/CDO. The last row in Panel A gives summary data for the Repo-Haircut Index, which is defined as the equally-weighted average haircut for all nine asset classes. For each category, the mean and standard deviation of the repo haircuts during the respective time periods are shown.

From these statistics I can identify important trends leading up to the Crisis. In general, the first half of 2007 looks "normal" in the sense that it is prior to the panic. For example, the third category of A-AAA ABS-Auto/CC/SL has an average repo haircut of zero in the first half of 2007. However, looking at the second half of 2007, it is clear that the effects of the Crisis hit when the repo haircut jumps to 8 percent. Concerns about the liquidity of markets for the bonds used as collateral led to increases in repo haircuts, which coupled with declining asset values resulted in an effectively insolvent U.S. banking system for the first time since the Great Depression (Gorton and Metrick 2009). The repo haircuts in each category follow a pattern of a rise in the second half of 2007 and a dramatic increase in 2008. In particular, the Repo-Haircut Index rises from zero in the first half of 2007 to nearly 30 percent at the peak of the Crisis in the last quarter of 2008. The rise in repo haircuts constitutes the run on repo.

Repo haircuts are zero for all asset classes in the pre-Crisis period, but both Figure 1 and Figure 2 essentially document the unfolding of the panic in the timeline of the Crisis. Figure 1 groups the

<sup>10</sup> The Bank for International Settlements (2010) has a small amount of survey-based data from June 2007 to June 2009.

<sup>11</sup> All variables given in Table 1 are defined in the Appendix.



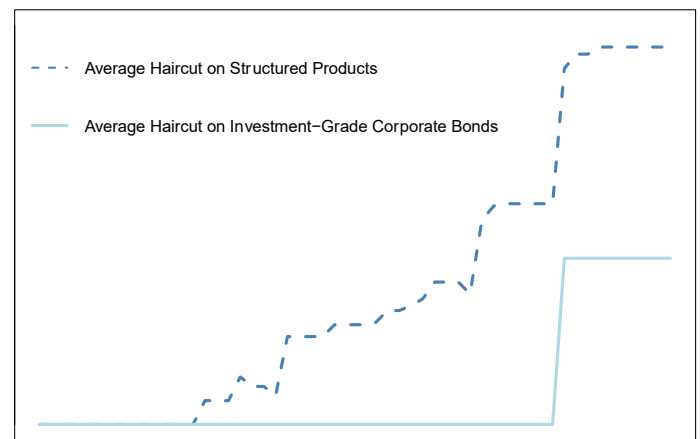
**Figure 1.** Repo Haircuts on Different Categories of Asset Classes.

*Investment-grade corporate bonds include BBB+/A Corporates and AA-AAA Corporates. Non-surprime related include A-AAA ABS-Auto/CC/SL, AA-AAA ABS-RMBS-CMBS, <AA ABS-RMBS/CMBS, and AA-AAA CLO. Subprime related include Unpriced ABS/MBS/All Sub-Prime, AA-AAA CDO, and Unpriced CLO/CDO.*

categories by their ratings into investment-grade corporate bonds (BBB+/A Corporates, AA-AAA Corporates), non-subprime related (A-AAA ABS-Auto/CC/SL, AA-AAA ABS-RMBS/CMBS, <AA ABS-RMBS/CMBS, AA-AAA CLO), and subprime related (Unpriced ABS/MBS/All Sub-Prime, AA-AAA CDO, Unpriced CLO/CDO). A notable dynamic in the chronology of the Crisis is that there was not a single shock that led to one jump in the repo haircuts, but a prolonged series of increases in repo haircuts, with the failure of Lehman Brothers being the tipping point of this build-up of systemic fragility (Gorton, Metrick, and Xie 2014). In particular, Figure 1 confirms that haircuts were higher on subprime related asset classes and these assets were eventually not acceptable as collateral in repo agreements. In other words, the repo haircuts reached an unprecedented 100 percent.

The panic portrayed in Figure 1 is the securitized bank run on repo. If the assumption is a benchmark repo market size of \$10 trillion, then an increase in the Repo-Haircut Index from zero (pre-Crisis) to 20 percent during the Crisis results in a \$2 trillion shortage of repo market financing.<sup>12</sup> In theory, if an asset has a market value of \$100 and a bank sells it for \$80 with an agreement to repurchase it for \$88, then the repo rate is 10 percent  $[(88-80)/80]$  and the haircut is 20 percent  $[(100-80)/100]$ . Further, selling the underlying collateral to raise the \$2 trillion difference in the Crisis drives asset prices down, which then reinforces the cycle: lower prices, less collateral, more concerns about solvency, and ever increasing haircuts (Gorton and Metrick 2009).

A loss of confidence is found with the significant haircuts faced by the non-subprime related group that has nothing to do with subprime mortgages, as Figure 1 shows. The only caveat is its exposure to securitization. This loss of confidence can be driven by psychological phenomena. The heightened uncertainty of subprime increases feelings of fear, and the subsequent anxiety effect



**Figure 2.** Average Haircut on Structured Products Versus Average Haircut on Investment-Grade Corporate Bonds. The loss in confidence is confirmed with the comparison between the average haircut on structured products and the average haircut on investment-grade corporate bonds.

results in more conservative behavior that spreads throughout the banking system via contagion and informational social influence. This misperception of a group (i.e. market) norm that leads people acting at variance with their private beliefs out of a concern for the social consequences is referred to as pluralistic ignorance. The bias towards other categories of asset classes is due to a representativeness heuristic, which is the process whereby judgements of likelihood (i.e. risk) are based on assessments of similarity between group prototypes (i.e. subprime). Figure 2 confirms this loss of confidence with the comparison between the average haircut on structured products and the average haircut on investment-grade corporate bonds.<sup>13</sup> Corporate bonds, despite no contagious effect of subprime related, see a haircut increase from zero to 25 percent, consistent with the notion that “subprime risk, even though not large by itself, has been spread inside and outside the banking system, globally and domestically, and no one knows where it is” (Gorton 2010).

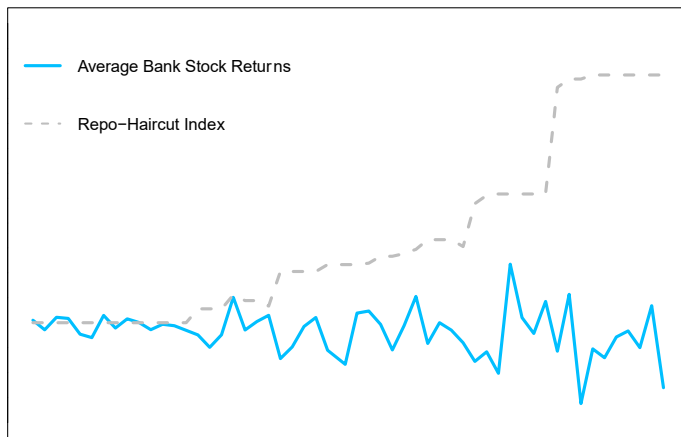
### Bank Stock Returns Data

Wharton Research Data Services (WRDS) is one of the main data sources for my analysis, specifically the Center for Research in Security Prices (CRSP) databases. CRSP maintains the largest and most comprehensive proprietary historical databases in stock market research, with daily stock prices, dividends, and shares outstanding data for companies listed on the NYSE, AMEX, and NASDAQ. Specifically, I use publicly available panel data from the CRSP U.S. Stock Database. The initial panel data was collected using the U.S. Securities and Exchange Commission Division of Corporate Finance Standard Industrial Classification (SIC) Code List, which indicates that company’s type of business. I used the SIC Codes for National Commercial Banks (6021), State Commercial Banks (6022), and Commercial Banks, Not Elsewhere Classified (6029) to collect the daily holding period returns for 366 banks from 2007Q1 through 2009Q1. Some banks were missing a few ob-

<sup>12</sup> \$10 trillion is an estimate based on the total assets in the regulated banking sector (Geithner 2008).

<sup>13</sup> Structured products include A-AAA ABS-Auto/CC/SL, AA-AAA ABS-RMBS/CMBS, <AA ABS-RMBS/CMBS, Unpriced ABS/MBS/All Sub-Prime, AA-AAA CLO, AA-AAA CDO, and Unpriced CLO/CDO.





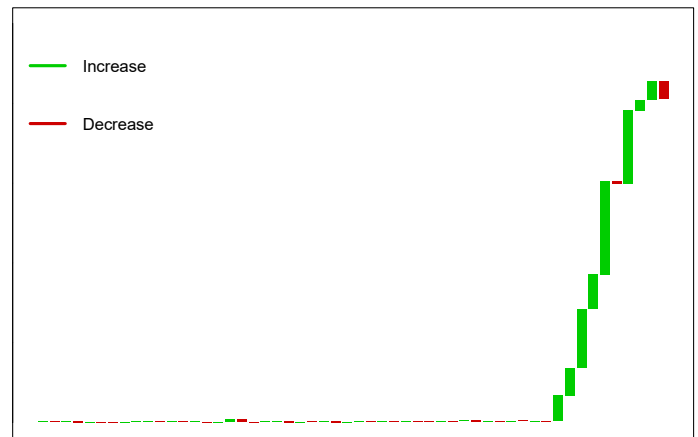
**Figure 3.** *Average Bank Stock Returns Versus Repo-Haircut Index. The average bank stock returns and the Repo-Haircut Index have a divergent relationship.*

servations due to the date of the private company going public, and vice versa, so the total observations for all banks is 160,489. Stock returns have shared variation due to stock-market risk factors (i.e. overall market factor and factors related to firm size and book-to-market equity), and they are linked to bond returns through shared variation in the bond-market risk factors (i.e. maturity and default risks) (Fama and French 1993). This database is characterized by its unique permanent identifiers that allow for clean and accurate backtesting, time-series and event studies, measurement of performance, accurate benchmarking, and securities analysis. It contains end-of-day and month-end prices on all listed NYSE, AMEX, and NASDAQ common stocks along with basic market indices, and includes the most comprehensive distribution information available, with the most accurate total return calculations.

I manually construct the dependent variable of interest from the raw data, the bi-weekly holding period returns. Subsequently, I manually construct the excess return on the bank stock ( $R_i - R_f$ ) by subtracting the risk-free rate of return from the bank stock rate of return. The calculation for bi-weekly holding period returns involves making sure the timing with the final repo haircut data is correct. The academic convention for calculating the bi-weekly holding period returns is as follows: for 2007Q1 through 2009Q1, collect the closing prices for trading days for the 366 banks. Then, use bi-weekly prices to calculate bi-weekly returns for each bank. In this way, the bi-weekly returns correspond to each respective bank in the panel data.

Further modification of the bi-weekly bank stock returns is needed to provide a more accurate avenue for my analysis. Due to the effects a company's significant public announcements have on their stock price, I omitted observations with bi-weekly returns less than -50 percent and greater than 50 percent to get rid of outliers. Consequently, the filter enables me to remove the idiosyncratic shocks that are introducing noise into my analysis and focus on the systemic shocks. The final subset sample of bank stock returns contains 10,338 total observations for all 351 banks from 2007Q1-2009Q1.

Table 1 Panel B shows summary statistics for bank stock returns. This also includes  $R_i - R_f$ , the excess return on bank stocks. It is



**Figure 4.** *Total Reserve Balances (\$ Billions). Total reserve balances experience an upsurge.*

clear that the identifiable important trends, just like those of the repo haircut data, are in line with the timeline of the Crisis. In the first half of 2007, the normal state of affairs is that the average bank stock returns are zero. Just like the repo haircut trends, there is a change when the Crisis hits. There are decreases in the average bank stock returns in the second half of 2007, but the larger decreases are in 2008.

The repo market and stock market are similar as they both have heavy trading and are therefore characterized as liquid. The Securities Industry and Financial Markets Association (SIFMA) reported that the average daily trading volume in the repo market was about \$7.11 trillion in 2008, compared with the New York Stock Exchange's reported average daily trading volume of about \$80 billion in 2008.<sup>14</sup> I illustrate the relationship between the repo market and the stock market during the Financial Crisis in Figure 3. The display is of the average bank stock returns versus the Repo-Haircut Index and appears to show a divergent relationship between the two. Both measures experience a period of stability near zero until the beginning of the second half of 2007 when the first signal of danger arose. At this point, they gradually diverge until the average bank stock returns reaches -16.22 percent and the Repo-Haircut Index reaches 48.89 percent on approximately September 15, 2008, the peak of the Crisis. On this day, the bankruptcy-court filing of Lehman Brothers Holdings Inc. lead to a daily point plunge of the Dow Jones Industrial Average, falling 504.48 points, and heralded the near collapse of the interbank market in the subsequent weeks (Craig et al. 2008).<sup>15</sup> It is important to note that a financial crisis can take many forms, including a banking/credit panic or a stock market crash; but it differs from a recession, which is often the result of such a crisis.

#### Total Reserve Balances Data

Another data source is Federal Reserve Economic Data (FRED),

<sup>14</sup> The SIFMA number includes repo and reverse repo; half of \$7.11 trillion would be \$3.56 trillion (2008).

<sup>15</sup> Dow Jones Industrial Average (DJIA) is a price-weighted index that tracks 30 large, publicly-owned blue chip companies trading on the New York Stock Exchange (NYSE) and the NASDAQ (Ganti 2020).

which has more than 500,000 economic time series from 87 sources. The research division of the Federal Reserve Bank of St. Louis maintains this publicly available database. It covers banking, business/fiscal, consumer price indexes, employment and population, exchange rates, gross domestic product, interest rates, monetary aggregates, producer price indexes, reserves and monetary base, U.S. trade and international transactions, and U.S. financial data.

The initial data was gathered regarding the independent variable of interest, total reserve balances maintained with Federal Reserve banks. The initial 108 observations have a weekly frequency from 2007Q1 through 2009Q1. The total reserve balances maintained is the amount of balances institutions hold in accounts at Federal Reserve Banks that are available to satisfy reserve requirements; historically, this series excluded balances held in a reserve account for contractual clearing purposes. One indication of the quality of the data is its reliable source. The data has a few limitations: it is aggregated for all banks instead of data on a granular bank by bank basis; reserve computation and maintenance periods are bi-weekly, not weekly, and values repeat for 2 consecutive weeks; and all other datasets must be trimmed to sync the dates of observations. Due to the bi-weekly data limitation, I subset the data for bi-weekly observations and end up with 54 observations.

Table 1 Panel C displays summary statistics for total reserve balances. Interestingly, the magnitude at which the average total reserve balances are increasing from the first half of 2007 to the second half of 2007 is becoming smaller, from 4 percent to 2 percent. However, all of 2008 sees a sharp increase to 36 percent. This pattern is explained by the complementary relationship between the main elements of traditional banking and securitized banking. First, in traditional banking, reserves are regulated by requiring a fraction of deposits to be held in reserve to promote bank solvency and in emergencies these reserves can be replenished by borrowing from the central bank. In securitized banking, the analogue is repo haircuts in which counterparties set minimal levels of banks' assets in reserve when they borrow money through repo markets and no borrowing is available from the central bank. Second, deposit insurance is a government guarantee to pay depositors in the event of default; the analogue is collateral (i.e. cash treasury securities, loans, and securitized bonds) that the investor keeps if the bank defaults on the repurchase agreement. Third, deposit rates can be increased to attract deposits (i.e. cash) when reserves are low; the analogue is repo rates that can be raised to attract counterparties when funds are low. Finally, loans held on the balance sheet are the result of lent out cash raised; the analogue is loans repackaged and resold as securitized bonds when funds are lent out temporarily.

Figure 4 bridges the total reserve balances maintained with Federal Reserve banks. Total reserve balances held at the Federal Reserve include required reserves and any excess reserves that depository institutions choose to hold on top of the required reserves.<sup>16</sup> The figure shows that: (1) total reserve balances waver around \$10,000,000,000 pre-Crisis; but (2), total reserve balances skyrocket to a max of \$862,540,000,000 at the heart of the Crisis. The upsurge represents the implementation of the Emergency Eco-

nomics Stabilization Act of 2008, which moved up by three years the effective date of the Financial Services Regulatory Relief Act of 2006. On October 6, 2008, the legislation announced that the Federal Reserve would begin to pay interest on depository institutions' required and excess reserve balances (Board of Governors of the Federal Reserve System 2008). Overall, the figure shows that this was important for monetary policy because the Federal Reserve's various liquidity facilities initiated during the Financial Crisis caused upward pressure on excess reserves and placed downward pressure on the Federal funds rate.<sup>17</sup>

### Market Rate of Return and Risk-Free Rate of Return Data

In addition, Kenneth R. French is the publicly available data source for the Fama/French 3 Research Factors used in my regression analysis. Kenneth R. French is the Roth Family Distinguished Professor of Finance at the Tuck School of Business at Dartmouth College. He is an expert on the behavior of security prices and investment strategies. He and co-author Eugene F. Fama are well known for their research into the value effect and the three-factor model. Kenneth R. French provides a detailed description of the factor construction regarding the control variable of interest, the market rate of return minus the risk-free rate of return ( $R_m - R_f$ ), which is technically the market factor.  $R_m - R_f$ , the excess return on the market, is the value-weight return of all CRSP firms incorporated in the U.S. and listed on the NYSE, AMEX, or NASDAQ that have a CRSP share code of 10 or 11 at the beginning of month  $t$ , good shares and price data at the beginning of  $t$ , and good return data for  $t$  minus the one-month Treasury bill rate (from Ibbotson Associates).<sup>18</sup> The initial data on  $R_m - R_f$  includes a total of 108 observations on a weekly basis over a period from 2007Q1-2009Q1. The strength of the data is the description of the underlying construction of the market factor; but, its limitation is that there is no theoretical justification for the successful use of  $R_m - R_f$  as a risk factor in predicting the returns on stocks.

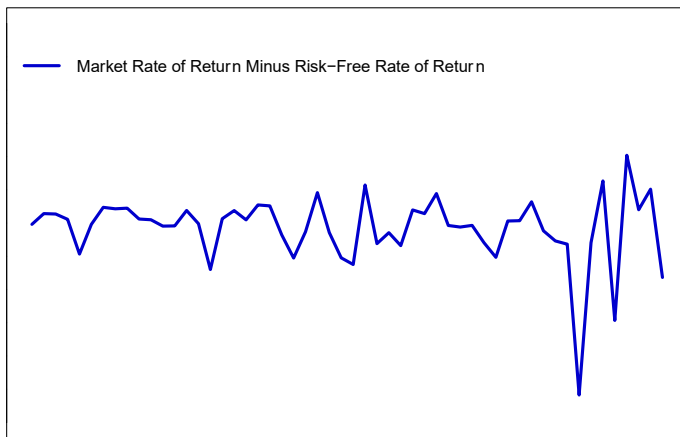
I manually constructed the bi-weekly  $R_m - R_f$  market factor. In order to do so, I ensure the timing with the final repo haircut data is correct. Using weekly data from the Fama/French 3 Research Factors from 2007Q1-2009Q1, I add back  $R_f$  to  $R_m - R_f$  to extract absolute values for  $R_m$  and  $R_f$ . Next, I compound the weekly into bi-weekly rates and subtract  $R_f$  from  $R_m$ . Thus, the final 54 observations of  $R_m - R_f$  accurately reflect the bi-weekly excess return on the market by way of compounding and is in line with the final repo haircut sample dates.

Table 1 Panel D gives summary statistics for  $R_m - R_f$  in the up and down market conditions. Positive market excess returns are 48 percent (26 of 54 weeks) of the observations. In up market conditions,  $R_m - R_f$  standard deviations are marginally lower than in down market conditions. Before the Crisis, the average  $R_m - R_f$  is 1 percent; in the Crisis period, the average  $R_m - R_f$  decrease to -2 percent. Even though the magnitude of the average  $R_m - R_f$  is small and the change between series is slight, the percent ob-

<sup>17</sup> To learn more about the Federal Reserve's credit and liquidity programs and the balance sheet, go to Board of Governors of the Federal Reserve System (2017).

<sup>16</sup> See Board of Governors of the Federal Reserve System (2020a) for a description of reserve requirements and how they are calculated.

<sup>18</sup> See Fama and French (1993), "Common Risk Factors in the Returns on Stocks and Bonds", for a complete description of the factor returns.



**Figure 5.** Excess Return on Market ( $R_m - R_f$ ).  $R_m - R_f$  fluctuates back and forth.

servations actually have back and forth fluctuations between -6.99 to 5.73 from 2007Q1 through 2008Q3 and -25.88 to 10.20 from 2008Q4 through 2009Q1, as shown in Figure 5.

Most important, the five common risk factors, one stock market factor being the overall market factor, seem to explain average returns on stocks and bonds (Fama and French 1993). Figure 6 compares the excess return on the market ( $R_m - R_f$ ) versus the average bank stock returns. The result documents how both measures move in tandem throughout the timeline of the Crisis. For example, both  $R_m - R_f$  and the average bank stock returns see a point plunge of 22.70 and 21.92 percentage points from -3.18 to -25.88 percent and 5.70 to -16.22 percent, respectively, at approximately the beginning of 2008Q4.

### Empirical Model

Repo haircuts are thought to have had many contagious external systemic effects during the Financial Crisis; however, the economics literature has focused on how repo haircuts internally affected the shadow banking system by driving the run on repo. To estimate the effect of repo haircuts on the external systems, I run a linear model regression of repo haircuts on the 9 different categories of asset classes of collateral on the return of bank stocks in the traditional banking system. The identifying assumption of the one-factor linear model regression is that bank stock returns are unlikely to be driving the effects in the repo market as repo haircuts are slow moving compared to bank stock returns and the haircut data effects are driven by broker dealer networks in the shadow banking system. Also, I am able to find correlation rather than causation in my empirical results because my analysis is only able to address co-movements of repo haircuts on bank stock returns without a structural model. The one-factor linear model regression to estimate this effect is specified as:

$$R_i - R_{f,t} = \alpha_0 + \beta_1 H_t^1 + \beta_2 H_t^2 + \beta_3 H_t^3 + \beta_4 H_t^4 + \beta_5 H_t^5 + \beta_6 H_t^6 + \beta_7 H_t^7 + \beta_8 H_t^8 + \beta_9 H_t^9 + \beta_{10} \text{TotalReserves}_t + \beta_{11} R_m - R_{f,t} + \epsilon_{i,t},$$

### Equation 1.

where  $t$  is time on a bi-weekly time index,  $R_i - R_{f,t}$  is the excess



**Figure 6.** Excess Return on Market ( $R_m - R_f$ ) Versus Average Bank Stock Returns. The excess return on the market ( $R_m - R_f$ ) and the average bank stock returns move in tandem.

bank stock returns on bank  $i$  at time  $t$ ,  $\alpha_0$  is a constant,  $H_t^1$  through  $H_t^9$  are the repo haircuts for the 9 different categories of asset classes of collateral,  $\text{TotalReserves}_t$  is the total reserve balances maintained with Federal Reserve banks, and  $R_m - R_{f,t}$  is the excess market return. Note,  $H^1$  through  $H^9$  are defined, in order, as follows: BBB+/A Corporates, AA-AAA Corporates, A-AAA ABS-Auto/CC/SL (auto/credit cards/student loans), AA-AAA ABS-RMBS/CMBS, <AA ABS-RMBS/CMBS, Unpriced ABS/MBS/All Sub-Prime, AA-AAA CLO, AA-AAA CDO, and Unpriced CLO/CDO. Since repo haircuts are slow moving and they significantly co-move and vary over my time period, I take first differences of Equation 1 and normalize all changes by their level in the previous period:

$$R_i - R_{f,t} = \alpha_0 + \beta_1 \Delta H_t^1 + \beta_2 \Delta H_t^2 + \beta_3 \Delta H_t^3 + \beta_4 \Delta H_t^4 + \beta_5 \Delta H_t^5 + \beta_6 \Delta H_t^6 + \beta_7 \Delta H_t^7 + \beta_8 \Delta H_t^8 + \beta_9 \Delta H_t^9 + \beta_{10} \Delta \text{TotalReserves}_t + \beta_{11} R_m - R_{f,t} + \epsilon_{i,t},$$

### Equation 2.

where the  $\Delta$  prefix indicates the absolute change of the variable. Throughout my analysis, all references to “changes” will be “absolute changes”, aside from  $\Delta \text{TotalReserves}_t$ , which is “percentage change”.

I include the market factor ( $R_m - R_f$ ) as a control variable because fluctuations that may vary by market during the Financial Crisis could affect stock prices and thus bank stock returns. Also,  $R_m - R_f$  is the main driving factor of stock returns in the Fama and French Three-Factor Model. The other two research factors are firm size (SMB: “small minus big”) and book to market equity (HML: “high minus low”). Fama and French (1993) confirm this decision: “not surprisingly, the excess return on the market portfolio of stocks,  $R_m - R_f$ , captures more common variation in stock returns than the term-structure factors”. The Fama and French Three-Factor Model is an asset pricing model that expands on the capital asset pricing model (CAPM) by adding size risk and value risk factors to the market risk factor in CAPM.<sup>19</sup> This enhanced model considers

<sup>19</sup> The Capital Asset Pricing Model (CAPM) describes the relationship between systematic risk and expected return for assets, particularly stocks. CAPM is widely used throughout finance for pricing risky securities and generating expected returns for assets given the risk of those assets and cost of capital.

the fact that value and small-cap stocks outperform markets on a regular basis; by including these two additional factors, the model adjusts for this outperforming tendency, which is thought to make it a better tool for evaluating manager performance. While I don't incorporate SMB or HML into my regression analysis, I do add total reserve balances as an additional independent variable. I believe this additional variable co-moves with bank stock returns during the Crisis for reasons I aim to understand further in my analysis.

Since I am working with the norm of finance data dimensionality in panel form, it is important that I adjust standard errors for correlation either across firms or across time in my regression estimations to enhance the statistical reliability of my results. In an ideal linear model regression on panel data, the assumption is that there are independent and identically distributed (i.i.d.) random variables.<sup>20</sup> However, in a finance panel, it is unlikely for the residuals to be uncorrelated either across time or across firms (Thompson 2011). Since systemic shocks in the finance industry can cause market wide co-movement across all bank stock returns, I cluster the standard errors by company to account for the fact that systemic shocks will produce correlation between firms at specific points in time (Thompson 2011). The econometrics approach I use to account for this challenge is a version of the Fama-MacBeth regression.

The Fama-MacBeth two-step regression is a practical way of testing how risk factors describe portfolio or asset returns. The goal is to find the premium from exposure to these factors. In the first step, each portfolio's return is regressed against one or more factor time series to determine how exposed it is to each one (the "factor exposures"). In the second step, the cross-section of portfolio returns is regressed against the factor exposures, at each time step, to give a time series of risk premia coefficients for each factor. The insight of Fama-MacBeth is to then average these coefficients, once for each factor, to give the premium expected for a unit exposure to each risk factor over time (Fama and MacBeth 1973).<sup>21</sup> Since the gran-

20 A common assumption about data produced by complex systems that often exhibit fluctuations and variability is that observations are independent and identically distributed (i.i.d.). i.i.d. means that in a given a set of data  $\{x_i\}$ , each of these  $x_i$  observations is an independent draw from a fixed ("stationary") probabilistic model. Independence means that  $\Pr(x_1)$  and  $\Pr(x_2) = \Pr(x_1) \Pr(x_2)$ . That is, the probability of observing two values  $x_1$  and  $x_2$  is simply the probability of observing  $x_1$  multiplied by the probability of observing  $x_2$ . This implies what is called conditional independence,  $\Pr(x_2 | x_1) = \Pr(x_2)$ .

21 See (Fama and MacBeth 1973) for the empirical tests. In equation form, for  $n$  portfolio or asset returns and  $m$  factors, in the first step the factor exposure  $\beta$ s are obtained by calculating  $n$  regressions, each one on  $m$  factors (each equation in the following represents a regression):

$$\begin{aligned} R_{1,t} &= \alpha_1 + \beta_{1,F_1} F_{1,t} + \beta_{1,F_2} F_{2,t} + \cdots + \beta_{1,F_m} F_{m,t} + \epsilon_{1,t} \\ R_{2,t} &= \alpha_2 + \beta_{2,F_1} F_{1,t} + \beta_{2,F_2} F_{2,t} + \cdots + \beta_{2,F_m} F_{m,t} + \epsilon_{2,t} \\ &\vdots \\ R_{n,t} &= \alpha_n + \beta_{n,F_1} F_{1,t} + \beta_{n,F_2} F_{2,t} + \cdots + \beta_{n,F_m} F_{m,t} + \epsilon_{n,t}, \end{aligned} \quad (1)$$

where  $R_{i,t}$  is the return of portfolio or asset  $i$  ( $n$  total) at time  $t$ ,  $F_{j,t}$  is the factor  $j$  ( $m$  total) at time  $t$ ,  $\beta_{i,F_m}$  are the factor exposures, or loadings, that describe how returns are exposed to the factors, and  $t$  goes from 1 through  $T$ . Notice that each regression uses the same factors  $F$ , because the purpose is to determine the exposure of each portfolio's return to a given set of factors.

The second step is to compute  $T$  cross-sectional regressions of the returns on the  $m$  estimates of the  $\beta$ s (call then  $\hat{\beta}$ ) calculated from the first step. Notice that each regression uses the same  $\beta$ s from the first step, because now the goal is the expo-

ularity of the repo haircut and total reserve balances data is limited and does not vary across banks, I run the second step by regressing bank stock returns against repo haircuts at each company, rather than time, step.

While there is a small literature on sale and repurchase agreement haircuts due to limited official statistics on the overall size of the repo market and haircuts, this paper in essence extends and refines Gorton and Metrick's "Securitized Banking and Run on Repo" study from 2009. They discover that concerns about the liquidity of markets for the bonds used as collateral led to increases in repo haircuts (Gorton and Metrick 2009). While I also use the same repo haircut dataset to find that the Panic of 2007-2008 transpired as increasing haircuts composed a run on repo at the nexus of the Crisis, my study is not identical; it has a few differentiating factors that explain the novelty of my research and the differing results:

- I address one question not explored in the 2009 study by Gorton and Metrick: Do repo haircut effects, subsequently a run on repo, in the securitized banking system differ from those in the traditional banking system (measured via bank stock returns) in how they affect financing performance during the Financial Crisis?
- Bank stock returns are on the left-hand side of the equation, rather than repo haircuts, and they depend on repo haircuts on the right-hand side, rather than the ABX index, a proxy for fundamentals in the subprime mortgage market; the LIB-OIS, the spread between the LIBOR rate (for unsecured interbank borrowing), and OIS, the rate on an overnight interest swap (a proxy for the risk-free rate); VOL, the average absolute change in spreads over a future period of time (a proxy for expected volatility); and  $X$ , a vector of control variables.

These two points are interesting for many reasons. As mentioned earlier, the 2007-2009 Financial Crisis was special because it was a run on repo in the securitized banking system, instead of in the traditional banking system, and these securitized banking activities were central to the operations of former investment banks while supplementing traditional banking activities of commercial banks. One inference deducted from these dynamics is how capital affects a bank's performance and how these effects vary across banking crises, market crises, and normal times. One piece of literature regarding this topic is Berger and Bouwman's 2013 study. The findings from this paper show that: (1) capital helps small banks to increase their probability of survival and market share at all times

sure of the  $n$  returns to the  $m$  factor loadings over time:

$$\begin{aligned} R_{i,1} &= \gamma_{1,0} + \gamma_{1,1} \hat{\beta}_{i,F_1} + \gamma_{1,2} \hat{\beta}_{i,F_2} + \cdots + \gamma_{1,m} \hat{\beta}_{i,F_m} F_m + \epsilon_{i,1} \\ R_{i,2} &= \gamma_{2,0} + \gamma_{2,1} \hat{\beta}_{i,F_1} + \gamma_{2,2} \hat{\beta}_{i,F_2} + \cdots + \gamma_{2,m} \hat{\beta}_{i,F_m} F_m + \epsilon_{i,2} \\ &\vdots \\ R_{i,T} &= \gamma_{T,0} + \gamma_{T,1} \hat{\beta}_{i,F_1} + \gamma_{T,2} \hat{\beta}_{i,F_2} + \cdots + \gamma_{T,m} \hat{\beta}_{i,F_m} F_m + \epsilon_{i,T}, \end{aligned} \quad (2)$$

where the returns  $R$  are the same as those in Equation (1),  $\gamma$  are regression coefficients that are later used to calculate the risk premium for each factor, and in each regression  $i$  goes from 1 through  $n$ .



Bank Stock Returns										
Intercept										-0.01***
										(-9.60)
$\Delta$ BBB+/A Corporates										-7.92***
										(-9.58)
$\Delta$ AA-AAA Corporates										-7.92***
										(-9.58)
$\Delta$ A-AAA ABS-Auto/CC/SL										-1.00***
										(-8.13)
$\Delta$ AA-AAA ABS-RMBS/CMBS										-7.03***
										(-10.12)
$\Delta$ <AA ABS-RMBS/CMBS										10.01***
										(11.25)
$\Delta$ Unpriced ABS/MBS/All Sub-Prime										0.15**
										(2.25)
$\Delta$ AA-AAA CLO										-1.43***
										(-9.76)
$\Delta$ AA-AAA CDO										2.65***
										(12.56)
$\Delta$ Unpriced CLO/CDO										-1.73*
										(-1.71)
$\Delta$ TotalReserves										0.06***
										(10.24)
$R_m - R_f$										0.92***
										(18.77)
$\Delta H^1$	$\Delta H^2$	$\Delta H^3$	$\Delta H^4$	$\Delta H^5$	$\Delta H^6$	$\Delta H^7$	$\Delta H^8$	$\Delta H^9$	$\Delta$ TotalReserves	$R_m - R_f$
<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	0.09	<0.01	<0.01

**Table 2.** Repo Haircuts Regression Results. For bank stock returns, I estimate Equation 2 using bi-weekly data from January 3, 2007 to January 21, 2009.  $\Delta H^1$  through  $\Delta H^9$  is the absolute change of the repo haircut on the asset class of collateral, respectively: BBB+/A Corporates, AA-AAA Corporates, A-AAA ABS-Auto/CC/SL (auto/credit cards/student loans), AA-AAA ABS-RMBS/CMBS, <AA ABS-RMBS/CMBS, Unpriced ABS/MBS/All Sub-Prime, AA-AAA CLO, AA-AAA CDO, and Unpriced CLO/CDO.  $\Delta$ TotalReserves is the percentage change of the total reserve balances maintained with Federal Reserve banks.  $R_m - R_f$  is the excess return on the market. *t*-statistics are given in parentheses below the coefficient estimates. The last row reports *p*-values for the independent variables. The samples are restricted to observations that are used in the one-factor linear model regression. \* $p < 0.10$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$ .

(during banking crises, market crises, and normal times) and (2) capital enhances the performance of medium and large banks primarily during banking crises (Berger and Bouwman 2013). So, changes in capital can result in gains or losses in market share that may have significant impacts on a company's stock performance.

## RESULTS

Table 2 summarizes Equation 2's one-factor linear model regression results with repo haircuts, total reserves, and  $R_m - R_f$  regressed on bank stock returns. The coefficient estimates show that bank stock returns are significantly correlated to total reserves,  $R_m - R_f$ , and all 9 of the different categories of asset classes of collateral repo haircuts: BBB+/A Corporates, AA-AAA Corporates, A-AAA ABS-Auto/CC/SL (auto/credit cards/student loans), AA-AAA ABS-RMBS/CMBS, <AA ABS-RMBS/CMBS, Unpriced ABS/MBS/All Sub-Prime, AA-AAA CLO, AA-AAA CDO, and Unpriced CLO/CDO. The statistically significant variables hold explanatory power for the path of the run on repo traced from the securitized banking system to the traditional banking system measured via bank stock returns.

Rows 2 through 10 in Table 2 display the results of the repo haircut variables. The partial slope coefficient for both BBB+/A Corporates and AA-AAA Corporates is negative and significant at the 1 percent level; an increase in BBB+/A Corporates or AA-AAA Corporates repo haircuts of one percentage point is associated with a decrease of 7.92 percentage points of bank stock returns, holding the other

variables constant. Interestingly, the effect of the investment-grade corporate bonds on bank stock returns is greater in magnitude to the majority of the structured products, indicating the balance sheet bond rating forecasting inequalities in stock returns consistent with the findings of Adrian, Etula, and Muir (2014). Banks holding more higher rated bonds on their balance sheets have inherently greater exposure to the associated risk profiles that possess predictive power of stock returns than banks holding lower rated bonds.

Holding all other variables constant, an A-AAA ABS-Auto/CC/SL repo haircut increase is correlated to a 1.00 percentage point decrease in bank stock returns. An increase in repo haircuts on AA-AAA ABS-RMBS/CMBS is associated with bank stock returns decreasing by 7.03 percentage points, holding the other variables constant. AA-AAA CLO repo haircuts affect bank stock returns with a resulting 1.43 percentage points decrease, holding constant the other variables. Unpriced CLO/CDO repo haircut increases, holding the other variables constant, are related to 1.73 percentage point bank stock return decreases. Surprisingly, <AA ABS-RMBS/CMBS, Unpriced ABS/MBS/All Sub-Prime, and AA-AAA CDO are positively correlated with bank stock returns.

Row 11 of Table 2 displays the results of the total reserves variable. The partial slope coefficient for total reserves is positive and significant at the 1 percent level; an increase in total reserves of one percentage point is associated with an increase of 0.06 percentage point of bank stock returns, holding the other variables constant. Row 12 of Table 2 displays the results of the control variable. The coefficient on  $R_m - R_f$  is significant at the 1 percent level. An in-



crease in  $R_m - R_f$  is associated with an increase of 0.92 percentage point on bank stock returns, holding the other variables constant. As a contribution to the economics literature, which concludes that repo haircuts have internal negative effects on the shadow banking system by driving the run on repo, I find a significant negative external effect of repo haircuts on the traditional banking system by driving the decline in bank stock returns.

## CONCLUSION

This paper investigates what the effect of repo haircuts are on bank stock returns during the Financial Crisis. The abundance of significant effects of repo haircuts on bank stock returns suggests that the effect of repo haircuts on the traditional banking system has been understated in previous literature due to a gap in comprehensive haircut data. The one-factor linear model regression results of the bank stock returns effects of repo haircuts find significant negative coefficients on BBB+/A Corporates, AA-AAA Corporates, A-AAA ABS-Auto/CC/SL, AA-AAA ABS-RMBS/CMBS, AA-AAA CLO, and Unpriced CLO/CDO, along with significant positive coefficients on <AA ABS-RMBS/CMBS, Unpriced ABS/MBS/All Sub-Prime, AA-AAA CDO, total reserves, and  $R_m - R_f$ , suggesting the former are positive and the latter are negative important factors affecting bank stock returns.

The fundamental assumption of this paper's narrative is that bank stock returns are unlikely to be driving the effects in the repo market. For this identifying assumption of the one-factor linear model regression to be the case, it must be that the effect of repo haircuts on bank stock returns is more robust than the reverse. It is surely the case as repo haircuts are slow moving compared to bank stock returns and the haircut data effects are driven by broker dealer networks in the shadow banking system. Further, haircuts exist due to sequential transactions (i.e. trading chains) and the haircut size is a function of (1) the default probabilities of the borrower, (2) the liquidity needs of the lender, (3) the default probability of the lender in a subsequent repo transaction, and (4) the information sensitivity of the collateral (Dang, Gorton, and Holmström 2010b). However, this assumption can be clarified through a statistical robustness check: (1) regress **bank stock returns**<sub>*t*</sub> on **repo haircuts**<sub>*t*</sub> (to find significant correlation), (2) regress **bank stock returns**<sub>*t+1*</sub> on **repo haircuts**<sub>*t*</sub> (to find significant correlation given repo traders can't know today bank stock returns tomorrow and bank stock returns tomorrow can't affect repo haircuts today), (3) regress **repo haircuts**<sub>*t+1*</sub> on **bank stock returns**<sub>*t*</sub> (to find insignificant correlation). If these 3 checks are true, then there is evidence that the causality flows from repo haircuts to bank stock returns, not vice versa.

The linear model regression generates some results consistent with previous literature and others that differ slightly, offering important implications for policy regarding repos. The preceding analysis suggests that the line between information sensitivity and insensitivity has moved because of the subprime shock (i.e. previously information-insensitive tranches are now sensitive). This case implies policies with the goal to design securities, including debt and securitization, such that it does not pay to speculate in these bonds. For example, when the asymmetric information about the holders of subprime risks becomes pressing, increasing haircuts provides a

way to recreate (through retransferring) information-insensitive debt (Dang, Gorton, and Holmström 2010a, 2010b). Consequently, policymakers should be mindful of this in their dealings with repos.

The findings regarding differences in securitized banking system and traditional banking system financing performance following increased haircuts during the Financial Crisis are interesting. The most relevant debate for academics, financiers, and politicians, and the main motivation for this paper, is whether there is an underlying economic relationship causing the co-movement between repo haircuts and bank stock returns, where there really should be zero relationship. The answer to this question has important policy implications regarding the Federal Reserve's continuous role in monitoring repo infrastructure and recommending regulatory reforms to ensure these markets remain stable sources of funding during periods of market stress. Future research could focus on either testing my identifying assumption that bank stock returns are unlikely to be causing the effects in the repo market or exploring a contemporaneous factor not captured in the market factor that is driving the co-movement of repo haircuts and bank stock returns by including more relevant control variables to tease out the effect of repo haircuts.

## APPENDIX: GLOSSARY

**AA-AAA ABS RMBS/CMBS:** Residential mortgage-backed security (RMBS) or commercial mortgage-backed security (CMBS) with ratings between AA and AAA, inclusive.

**<AA ABS RMBS-CMBS:** Residential mortgage-backed security (RMBS) or commercial mortgage-backed security (CMBS) with ratings between AA and AAA, inclusive.

**AA-AAA CDO:** Collateralized debt obligations (CDO) with ratings between AA and AAA, inclusive.

**AA-AAA CLO:** Collateralized loan obligations (CDO) with ratings between AA and AAA, inclusive.

**AA-AAA Corporates:** Corporate bonds rated between AA and AAA, inclusive.

**A-AAA ABS Auto/CC/SL:** Asset-backed securities (ABS) comprised of auto loans, credit-card receivables, or student loans, with ratings between A and AAA, inclusive.

**BBB+/A Corporates:** Corporate bonds rated between BBB+ and A, inclusive.

**Unpriced ABS/MBS, All Subprime:** All tranches of ABS, MBS and all subprime securitized bonds which do not have public pricing posted on Bloomberg or Reuters (two news services used by traders)

**Unpriced CDO/CLO:** All tranches of CDO and CLO securitized bonds which do not have public pricing posted on Bloomberg or Reuters (two news services used by traders)

**Repo-Haircut Index:** The equal-weighted average haircut for all

nine of the asset classes. Haircuts of 100 percent (= no trade) are included in this average.

**Bank Stock Returns:** A return is the change in the total value of an investment in a common stock over some period of time per dollar of initial investment.

**Total Reserve Balances:** Total reserve balances maintained with Federal Reserve banks is the amount of balances institutions hold in accounts at Federal Reserve Banks that are available to satisfy reserve requirements. The units are in millions of dollars and not seasonally adjusted.

**Rm – Rf:**  $R_m - R_f$ , the excess return on the market, is the value-weight return of all CRSP firms incorporated in the U.S. and listed on the NYSE, AMEX, or NASDAQ that have a CRSP share code of 10 or 11 at the beginning of month  $t$ , good shares and price data at the beginning of  $t$ , and good return data for  $t$  minus the one-month Treasury bill rate (from Ibbotson Associates).

**Ri – Rf:**  $R_i - R_f$  is the excess return on the bank stock.

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